THE STUDIES OF ELECTRO-MECHANICAL AND PHASE TRANSITIONS BEHAVIOUR OF LIQUID CRYSTAL MATERIALS, FOCUSING ON COLOR RANGE, RESPONSE TIME AND ENERGY CONSUMPTION

Synopsis submitted to IIMT University in partial fulfilment of the requirement for the award of the degree of

DOCTOR OF PHILOSOPHY

In

Physics

By

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Full Time

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1. INTRODUCTION

Liquid crystal(LC), which is exist in a mesophase between conventional solid and liquid crystal, possess unique electro-mechanical properties and phase transition behaviours that have garnered significant attention in research and technological enhancement. These materials capable to flow like a liquid while protect an ordered crystal structure, allowing for the of their optical properties under external stimuli such as electric fields, magnetic field, temperature, frequency, mechanical stress old reference. This duality of properties makes liquid crystals indispensable in various applications, such as display, sensor, smart windows etc.The fascination with liquid crystal began in the past 19th century, but it was not until the mid-20th century that their potential was fully recognize with the advent of liquid crystal displays (LCDs) **(Nosheen, 2019)**.

The fundamental understanding of their electro-mechanical and phase transition behaviors is critical to optimizing their performance in these applications the basis of their alinment. Liquid crystals can exist in different phases, such as Nematic, Smectic, and Cholesteric, each of with distinct molecular arrangement. The transition between these phases can be induced by changes in temperature, pressure, and the application of electric field, which affects the material's optical characteristics.

One of the key areas of research in liquid crystal materials is their electro-mechanical response, which involves the reorientation of molecules under an Electric field(electric force per unit charge). This recreatetion changes the way of light interacts with the LC, enabling the control of brightness, contrast, and color in display device. **(Prakash, Kumar, & Chauhan, 2022)**. The dielectric anisotropy of LC, which describes the difference in dielectric constant along different molecular axes, plays a crucial role. By applying new method of an electric field, the orientation of LC molecules can be adapted to achieve desired Optical electrical properties, for Example light modulation and polarization.

Phase transitions in liquid crystal materials are important, as they determine the material's phase, its optical and electro-mechanical properties **(Naemura, 2000)**. For instance, the Nematic phase, where molecules are aligned parallel but not line up in layers, is commonly used in displays due to its fast response time and ease of control with electric fields. The smectic phase, with its layered structure, offers different optical properties that can be advantageous in specific applications. Understanding these transitions at a molecular level

allows researchers to tailor liquid crystal materials for specific applications, enhancing their functionality and efficiency.

The study of electro-mechanical and phase transition behaviours in liquid crystal extend beyond displays (Popov et al., 2017). These materials are also being explored for use in tunable lenses, smart windows, and various types of sensors. In tunable lenses, the precise control of liquid crystal orientation allows for adjustable focal lengths, which can be beneficial in optical devices and wearable technologies. Smart windows, which can change transparency in response to an electric field(electric force per unit charge), utilize LC materials to provide energy-efficient controlling light and heat in buildings for privacy applications.

The study of electro-mechanical and phase transition behaviors of liquid crystal materials is a vibrant and evolving field with significant implications for technology and industry. By appreciating and manipulating these properties, Researchers enhance the performance and expand the applications of liquid crystal materials, driving innovation in display technology and beyond **(Darla & Varghese, 2012).**

2. LITERATURE REVIEW

The exploration of electro-mechanical and phase transition behaviors of liquid crystal has gained significant at traction in recent years due to its implications for advancing display technologies and other optical applications. This literature review examines three critical studies that contribute to understanding the complex dynamics of liquid crystals.

Caimi (2023) provides an in-depth analysis of the electro-mechanical and electro-opticl responses of ferro-electric nematic fluids. Ferroelectric nematic liquid crystals exhibit unique properties due to their spontaneous polarization, which significantly impacts their electro-optical behavior. Caimi's study delves into the mechanisms by which electric fields influence the orientation and alignment of ferroelectric nematic molecules. The research highlights the potential of these materials in enhancing the performance of display technologies by offering faster response times and better control over molecular alignment. This work is pivotal as it bridges the gap between theoretical models and practical applications, offering insights into optimizing(LCDs) liquid crystal displays and other electro-optical device.

Nosheen (2019) focuses on the flexo electro-optic properties of liquid crystals for phase modulation in her doctoral dissertation. Flexo electro-optic effects arise due to the coupling between the LC's elastic and dielectric properties. Nosheen's research investigates how these effects can be harnessed for phase modulation applications, which are crucial for improving the functionality of spatial light modulators and adaptive optics systems. The dissertation provides a comprehensive analysis of the molecular interactions and the influence of external electric fields on the flexo electro-optic response. Nosheen's findings are significant for developing liquid crystal-based devices that require precise control over light modulation, enhancing their efficiency and performance.

Prakash, Kumar, and Chauhan (2022) review the recent progress in arrange liquid crystal materials through the incorporation of nanoparticles. Their study in the journal "Liquids" emphasizes how nanoparticles can be used to manipulate alignment and stability of liquid crystals phases. The incorporation of nanoparticles offers a novel approach to achieving uniform alignment, which is essential for the consistent performance of liquid crystal devices. The review covers many types of nanoparticles, ie. metallic, dielectric, and magnetic, and their effects on the electro-mechanical properties of liquid crystal. Prakash et all. discuss the potential of nanoparticle-doped liquid crystals in reducing response times, enhancing thermal stability, and improving overall device efficiency. This research provides a complete overview of the advancement in liquid crystal technology facilitated by nanotechnology, highlighting the interdisciplinary nature of this field.

The study by Lee et al. (2023) focuses on the current advances in the electro-optical response of Polymer-Stabilized Cholesteric Lliquid Crystals (PSCLCs). PSCLCs have garnered attention for their unique helical structures and tunable optical properties, which make then suitable for a range of applications including displays, tunable filters, sensors. The research highlights how the polymer network within these liquid crystals can enhance their electro-optic performance by improving the stability and response times of the cholesteric phases. The researchers provide an depth analysis of the mechanisms behind the electro-optic modulation in PSCLCs, emphasizing the role of the polymer in matrix stabilizing the cholesterics structure against external perturbations. This stabilization leads to more consistent and reliable electro-optic responses, which are crucial for practical applications. Moreover, the study explores the impact of different types of polymer matrices on the electro optic properties, showcasing how tailoring the polymer composition and cross-linking density

can optimize the performance of PSCLCs. This research is significant as it offers a comprehensive understanding of how polymer stabilization can be leveraged to enhance the electro-optic characteristics of cholesteric LC, paving the way for more efficient and versatile optical devices.

Ye, Guo, et al. (2023) Provide a thorough study of the developments in polymer-stabilize liquid crystals (PSLCs), emphasizing their growing importance in modern technology. PSLCs are a class of materials where a polymer network is incorporated into the liquid crystal matrix, enhancing their structural integrity and electro-optic performance. This review covers a wide range of PSLCs, including nematic, smectic, and cholesteric phases, highlighting their unique properties and applications. The authors discuss the various methods used to synthesize and characterize PSLCs, noting how advances in polymer chemistry and processing techniques have LED to significant improvement in the stability and functionality of these materials. One of the key points of the review is the exploration of the interaction between the liquid crystal polymer network and molecules, which is critical for understanding the overall behavior of PSLCs under electric fields.

Prakash et al. (2020) Restudy the recent progress in the field of metal oxide-nanoparticles and liquid crystal composites, focusing on the synergistic effects that arise from combining these materials. The integration of metal oxide nanoparticles into liquid crystal matrices has been shown to significantly enhance the electro-optic properties of the resulting composites. The review highlights various types of metal oxide nanoparticles, including ZnO, TiO2, and Fe3O4, and their specific interactions with liquid crystal molecules. These interactions can lead to improved alignment, faster response times, and enhenced thermal stability of the liquid crystal phases.

3. RESEARCH GAP

Liquid Crystal (LC) materials have been extensively studied due to their unique electro-mechanical properties and phase transition behaviors, which are crucial for a large range of applications, particularly in display technologies. Despite the considerable research efforts in understanding the fundamental properties of liquid crystals, several gaps remain, particularly concerning the optimization of color range, response time, and energy consumption in liquid crystal displays (LCDs). This literature gap analysis identifies areas where further investigation is needed to enhance the performance and efficiency of LC-based devices.

Liquid crystals exhibit unique electro-mechanical properties and phase transitions, which are fundamental to their function in devices. Studies have primarily focused on the phase transition between nematic, smectic, cholesteric phases, as well as the effects of external electric fields on these transitions. However, a significant gap exists in understanding the complex interactions between electro-mechanical properties and phase transitions in novel liquid crystal materials, especially under varying temperature and electric field conditions.

Response time, which refers to the speed at which liquid crystals can reorient in response to used electric field, is another crucial parameter for better-performance displays, particularly in applications demand rapid refresh rates, such as in gaming or high-definition video playback. While extensive research has been conducted to understand the factors influencing response time, such as viscosity, dielectric anisotropy, and alignment layers, there remains a gap in the comprehensive understanding of how these factors interact at a microscopic level.

Energy consumption is a critical factor for the sustainability and usability of LCD technology, particularly in portable devices such as that smart phones and tablets, Where battery life is a key concern. While some studies have explored the optimization of backlighting and power management systems to reduce energy consumption, there is a gap in the literature regarding the intrinsic properties of liquid crystal materials that contribute to energy efficiency.

4. PROPOSED OBJECTIVES

Based on the literature review the objective of the proposed work are as follows:

I. Preparation of LC cell, Prepration & optimization LCs.
II. To determine the transmission (V-T) voltage transmission character, & display parameters.
III. Phase transition studies by microscope DSC.
IV. Morphological study (Optical Properties
V. Dielectric studies with temperature and frequency.

5. RESEARCH METHODOLOGY

5.1. SAMPLE PREPARATION:

The method of sample preparation will synthesize or procure various liquid crystal materials and To prepare LC cells with controlled thickness and contamination free.

5.2. MATERIAL CHARACTERIZATION:

Various techniques such as [POM] Polarizing Optical Microscopy, [DSC] Differential Scanning Calorimetry will be used to characterize the anatomical and liquid crystal's thermal properties, samples dielectrics & electro- optical.

5.3. CONDUCT ELECTRO-MECHANICAL TESTING:

The study will perform electro-optical measurements to assess COLOR range, response time, and energy consumption. Additionally, the research will conduct mechanical testing to evaluate stress-strain behaviour and electro-mechanical coupling.

5.4. DATA ANALYSIS:

The data analysis process will help to analyze the collected data using statistical methods to identify significant differences and correlations. The study will then employ computational modelling, such as finite element analysis (FEA), to simulate and interpret the results.

5. (a) SPECIFICATION OF INSTRUMENTS

Following facilities are available to carry out the proposed work in the liquid crystals lab physics department.

a) Temperature controller cum freezing /heating stage (from -196 - 600 °C, Linkam)

b) Polarizing optical microscope (Nikon Japan)

c) Transmission electron microscopy (TEM)

d) Impedance Analyzer (From 20 Hz to 10 kHz frequency range) (Wayne Kerr)

e) Function Generator (Tektronix) k) High voltage linear amplifier (FLC Electronics)

f) Weighing Balance (Sartorius) m) Ultrasonicator (Metrex)

g) He - Neon laser (Raman Scientific Instrument)

h) Photodetector (Instec USA)

i) Vibrating Sample Magnetometer [VSM]

j) Differential Scanning Calorimetry [DSC] Measurements.

6. EXPECTED OUTCOME OF THE RESEARCH

6.1. Enhanced Understanding of Electro-Mechanical Properties

One of the primary outcomes of this research will be a deeper considerate of the electro-mechanical properties of liquid crystal materials. This includes detailed insights into how these materials respond to electric fields and mechanical stress, and how these responses can be optimized. By systematically analyzing the behaviour of liquid crystals under various conditions, the research will elucidate the fundamental principles governing their electro-mechanical interactions. This knowledge is expected to pave the way for more efficient and effective applications in display technologies, sensors, and other electro-optic devices.

6.2. Optimized Response Time

The study is expected to determine the parameters that influence the response time of liquid crystal materials. Response time is a critical factor in applications such as displays and optical switches, where fast switching between states is required. By investigating the impact of various factors such as temperature, electric field strength, and material composition, the research will identify ways to minimize response time without compromising other properties. The findings will help in the design of faster and more reliable liquid crystal devices, enhancing their performance in practical applications.

6.3. Reduced Energy Consumption

An important outcome of the research will be strategies to reduce the energy consumption of liquid crystal materials during their operation. Energy efficiency is a crucial consideration in the design of sustainable and environmentally friendly technologies. The research will explore how different material formulations and operating conditions affect energy usage, with the goal of identifying low-energy configurations. The results will contribute to the development of energy-efficient displays, sensors, and other devices, aligning with global efforts to reduce energy consumption and carbon footprint.

6.4. Advanced Material Synthesis Techniques

The work is also expected to advance the techniques used for synthesizing and characterizing liquid crystal materials. Innovations in material synthesis, such as the incorporation of nanoparticles or the use of novel dopants, will be explored to enhance the properties of liquid

crystals. The outcomes will include optimized synthesis protocols that can be adopted by researchers and industry professionals to produce high-performance liquid crystal materials. These advancements will facilitate the creation of next-generation electro-optic devices with superior properties.

7. TIMELINE

- Month 1-6 : Literature review and research design
- Month 7-12:Writing and revising the synopsis
- Month 13-15:Synopsis final submission
- Month 16-19: Data collection
- Month 20-22: Data analysis
- After Month 23-28:Paper writing
- After Month 29-34:Paper submission to journal
- After Month 35-38: Submission to journal

REFERENCES

Andrienko, D. (2018). Introduction to liquid crystals. Journal of Molecular Liquids, 267, 520–541. https://doi.org/10.1016/j.molliq.2018.01.175

Bleszynski, M. S., Tursi, J. M., & Smith, C. M. (2021). Scientific developments of liquid crystal-based optical memory: A review. Reports on Progress in Physics, 80(1), 016601. https://doi.org/10.1088/0034-4885/80/1/016601

Boden, N., Bushby, R. J., Clements, J., Movaghar, B., Donovan, K. J., & Kreouzis, T. (1995). Mechanism of charge transport in discotic liquid crystals. Physical Review B, 52(19), 13274–13280. https://doi.org/10.1103/PhysRevB.52.13274

Brach, K., Hatakeyama, A., Nogues, C., Olesiak-Banska, J., Buckle, M., & Matczyszyn, K. (2018). Photochemical analysis of structural transitions in DNA liquid crystals reveals differences in spatial structure of DNA molecules organized in liquid crystalline form. Scientific Reports, 8(1), 4528. https://doi.org/10.1038/s41598-018-22958-8

Bunjes, H., & Rades, T. (2005). Thermotropic liquid crystalline drugs. Journal of Pharmacy and Pharmacology, 57(6), 807–816. https://doi.org/10.1211/0022357056268

Bushby, R. J., & Kawata, K. (2011). Liquid crystals that affected the world: Discotic liquid crystals. Liquid Crystals, 38(11-12), 1415–1426. https://doi.org/10.1080/02678292.2011.604907

Caimi, F. (2023). Electro-Optical and Electro-Mechanical Response of Ferroelectric Nematic Fluids.

Canli, N. Y., Özdemir, Z. G., Okutan, M., Güzeller, D., Ocak, H., & Eran, B. B. (2015). Dielectric Properties of 4-Cyano-4′-pentylbiphenyl (5CB): 4-[4-(S)-2-Methylbutoxybenzoyloxy]benzoic Acid (BAC) Composite. Molecular Crystals and Liquid Crystals, 623(1), 17–30. https://doi.org/10.1080/15421406.2015.1013833

Darla, M. R., & Varghese, S. (2012). Synthesis and characterisation of azomethine class thermotropic liquid crystals and their application in nonlinear optics. Liquid Crystals, 39(1), 63–70. https://doi.org/10.1080/02678292.2011.627126

De Almeida, R. R., Zhang, C., Parri, O., Sprunt, S., & Jakli, A. (2014). Nanostructure and dielectric properties of a twist-bend nematic liquid crystal mixture. Liquid Crystals, 41(12), 1661–1667. https://doi.org/10.1080/02678292.2014.957618

Forrest, B. J., & Reeves, L. W. (1981). New lyotropic liquid crystals composed of finite nonspherical micelles. Chemical Reviews, 81(1), 1–14. https://doi.org/10.1021/cr00041a001

Garti, N., Libster, D., & Aserin, A. (2012). Lipid polymorphism in lyotropic liquid crystals for triggered release of bioactives. Food & Function, 3(6), 700–713. https://doi.org/10.1039/c2fo10256a

Kamei, T., Utsumi, Y., Moritake, H., Toda, K., & Suzuki, H. (2003). Measurements of the dielectric properties of nematic liquid crystals at 10 kHz to 40 GHz and application to a variable delay line. Electronics and Communications in Japan, 86(7), 49–60. https://doi.org/10.1002/ecj.20300

Kim, D.-H., Jahn, A., Cho, S.-J., Kim, J. S., Ki, M.-H., & Kim, D.-D. (2014). Lyotropic liquid crystal systems in drug delivery: A review. Journal of Pharmaceutical Investigation, 45(1), 1–11. https://doi.org/10.1007/s40005-014-0141-8

Kovshev, E. I., Blinov, L. M., & Titov, V. V. (1977). Thermotropic Liquid Crystals and Their Applications. Russian Chemical Reviews, 46(5), 395–419. https://doi.org/10.1070/RC1977v046n05ABEH002532

Ros, M. B., Serrano, J. L., de la Fuente, M. R., & Folcia, C. L. (2005). Banana-shaped liquid crystals: A new field to explore. Journal of Materials Chemistry, 15(48), 5093–5098. https://doi.org/10.1039/b509222h

Sergeyev, S., Pisula, W., & Geerts, Y. H. (2007). Discotic liquid crystals: A new generation of organic semiconductors. Chemical Society Reviews, 36(12), 1902–1929. https://doi.org/10.1039/b417320g

Singh, S., & Dunmur, P. D. (2002). Liquid Crystals. World Scientific Publishing Co. Pte. Ltd.

Wang, L., Urbas, A. M., & Li, Q. (2018). Nature-Inspired Emerging Chiral Liquid Crystal Nanostructures: From Molecular Self-Assembly to DNA Mesophase and Nanocolloids. Advanced Materials, 32(1), e1801335. https://doi.org/10.1002/adma.201801335

Ye, Y., Guo, L., & Zhong, T. (2023). A review of developments in polymer stabilized liquid crystals. Polymers, 15(13), 2962.

Kowerdziej, R., Parka, J., Krupka, J., Olifierczuk, M., Nowinowski-Kruszelnicki, E., Jaroszewicz, L., & Chojnowska, O. (2013). Dielectric properties of highly anisotropic nematic liquid crystals for tunable microwave components. Applied Physics Letters, 103(17), 172902. https://doi.org/10.1063/1.4826845

Kumar, A., Varshney, D., & Prakash, J. (2020). Role of ionic contribution in dielectric behaviour of a nematic liquid crystal with variable cell thickness. Journal of Molecular Liquids, 303, 112520. https://doi.org/10.1016/j.molliq.2020.112520

Lagerwall, J. P. F., & Scalia, G. (2012). A new era for liquid crystal research: Applications of liquid crystals in soft matter nano-, bio- and microtechnology. Current Applied Physics, 12(6), 1387–1412. https://doi.org/10.1016/j.cap.2012.03.019

Lee, K. M., Marsh, Z. M., Crenshaw, E. P., Tohgha, U. N., Ambulo, C. P., Wolf, S. M., ... & Godman, N. P. (2023). Recent advances in electro-optic response of polymer-stabilized cholesteric liquid crystals. *Materials*, *16*(6), 2248.

Miniewicz, A., Gniewek, A., & Parka, J. (2002). Liquid crystals for photonic applications. Optical Materials, 21(1), 605–610. https://doi.org/10.1016/S0925-3467(02)00130-4

Naemura, S. (2000). Liquid-crystal-material technologies for advanced display applications. Journal of the Society for Information Display, 8(1), 5–9. https://doi.org/10.1889/1.1834535

Nosheen, S. (2019). *Flexo electro-optic Liquid Crystals for Phase Modulation* (Doctoral dissertation).

Popov, N., Honaker, L. W., Popova, M., Usol'Tseva, N., Mann, E. K., Jákli, A., & Popov, P. (2017). Thermotropic Liquid Crystal-Assisted Chemical and Biological Sensors. Materials, 11(1), 20. https://doi.org/10.3390/ma11010020

Prakash, J., Khan, S., Chauhan, S., & Biradar, A. (2020). Metal oxide-nanoparticles and liquid crystal composites: A review of recent progress. Journal of Molecular Liquids, 297, 112052. https://doi.org/10.1016/j.molliq.2019.112052

Prakash, J., Khan, S., Chauhan, S., & Biradar, A. M. (2020). Metal oxide-nanoparticles and liquid crystal composites: A review of recent progress. *Journal of Molecular Liquids*, *297*, 112052.

Prakash, J., Kumar, A., & Chauhan, S. (2022). Aligning liquid crystal materials through nanoparticles: A review of recent progress. *Liquids*, *2*(2), 50-71.

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